Detection of Delamination Defects in Plate Type Fuel Elements Applying an Automated C-Scan Ultrasonic System.

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Abstract

For the inspection of plate type fuel elements to be used in Research Nuclear Reactors it was applied an immersion pulse-echo ultrasonic technique. For that reason an automated movement system was implemented according to the axes X, Y and Z that allows to automate the test and to show the results obtained in format of C-Scan, facilitating the immediate identification of possible defects and making repetitive the inspection.

In this work problems found during the laboratory tests and factors that difficult the inspection are commented. Also the results of C-Scans over UMo fuel elements with pattern defects are shown. Finally, the main characteristics of the transducer with the one the better results were obtained are detailed

The Ultrasonic Technique

For the detection of delamination defects in plate type fuel elements the immersion pulse-echo ultrasonic technique was applied.

The inspection is carried out inside an ultrasonic tank that consists of a vat full of water where the plate is submerged and held by a support that assures its horizontal plane regarding to the scan system. The C-Scan system consists of stepper motors that allow the transducer movement according to the axes X, Y and Z with an adjustable resolution defined by the system operator. In this case a 0,5mm resolution step was used.

The system movements and graphic representations are controlled by a PC with software specially designed for this work. This software also controls the digitalizer board that converts the ultrasonic signals in the digital information that conforms the C-Scan image. The block diagram of the system is shown in fig.2

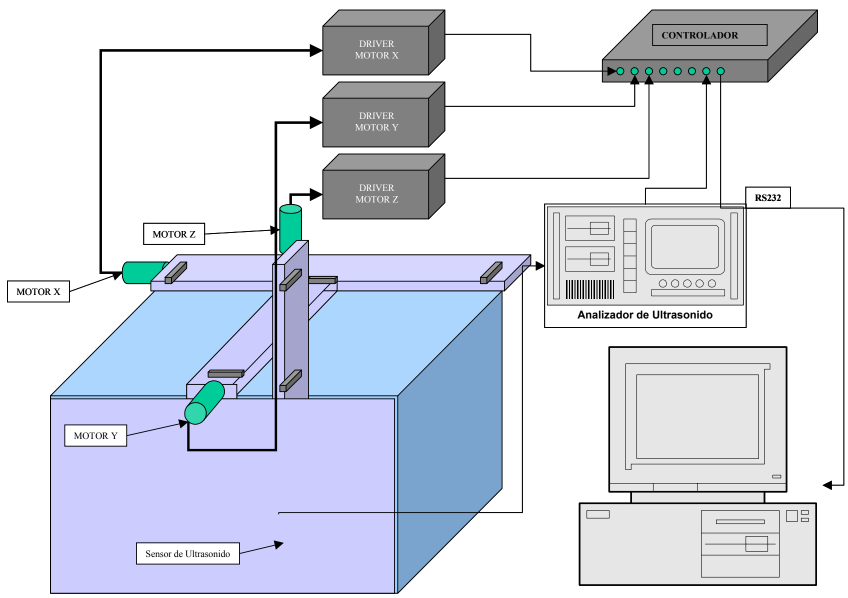


Fig. 1 - Scheme of the C-Scan Ultrasonic System

The most important component of the system is the transducer. It must assure the minimum sensitivity necessary to detect the pattern defects indicated in the specification [1]. Different focalized transducers of 5MHz, 10MHz, 15MHz and 22MHz were used. All of them were characterized obtaining their bandwidth and pulse length, two fundamental parameters to understand their ultrasonic response.

During the technique development different fuel plates of UAlx (2,5g/cm³), U_3Si_2 (Uranium Silicide, 4,8g/cm³) and UMo (Uranium-Molybdenum, 7,5g/cm³) with a thickness range between 1,35mm and 1,5mm were tested.

The minimum size of delamination defects that should be appreciated by this technique is the equivalent of a flat bottom hole of 2,5mm of diameter. These reference reflectors simulate a material discontinuity for the ultrasonic beam, which after crossing the first aluminum layer meets with an air zone, corresponding to the flat bottom hole (fig 2.), with an acoustic impedance lower than the one of the fuel core that produces a reflexion of the signal generating another echo at a minor distance than the plate bottom one. This behavior of the ultasonic wave allows the defect detection.

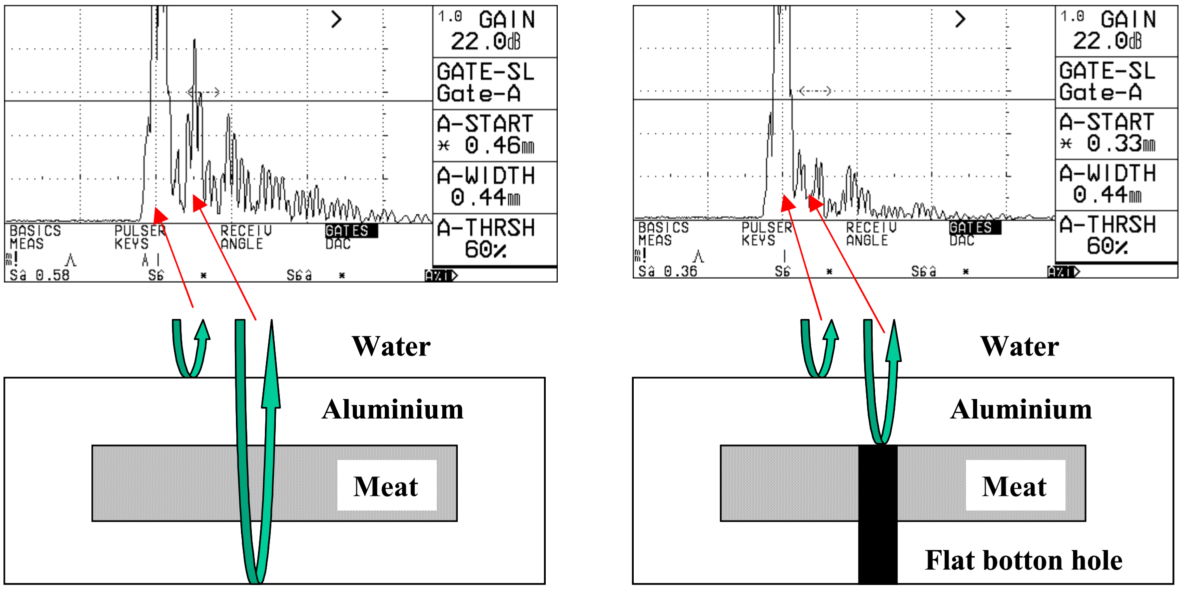


Fig. 2 - Behavior of the ultrasonic signal in relation to a flat bottom hole of Ø 2,5mm.

Results

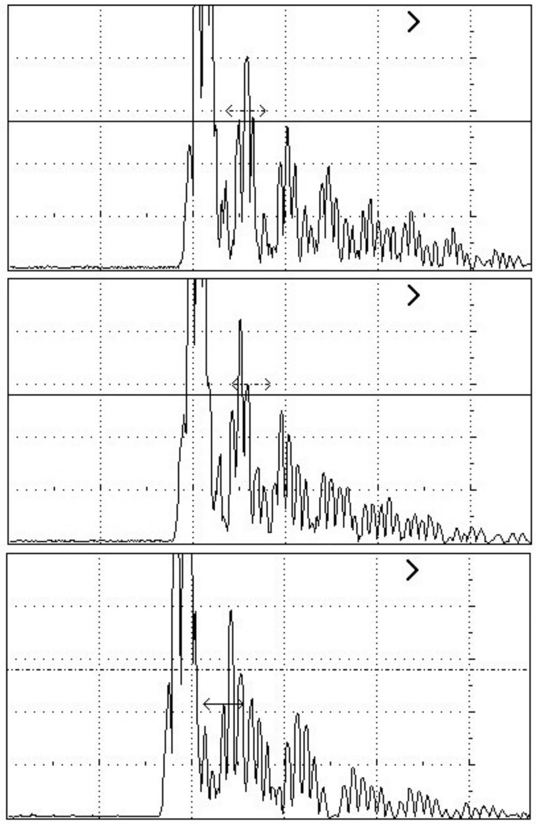
In accordance with the accomplished observations for the different compounds tested, it could be said that the ultrasonic dispersion that takes place inside the meat is the determinant factor to be considered in the feasibility analysis to obtain a reliable result.

This dispersion depends on several factors from which we can stand out the shape and size of the meat's particles, their density, and the difference between uranium's acoustic impedance and aluminium's acoustic impedance. Combined, these characteristics change the dispersion deppending on the position in the core zone, difficulting the calibration process.

The biggest problem that could be found is the decrease of the ultrasonic bottom echo's S/N ratio because of the high dispersion, this generates signals that can be mistaken with a delamination signal.

To minimize the dispersion problems it should be found the best relationship between the transducer's frecuency, the pulse length and the maximum resolution needed. This is a critical choice and must be studied every time the inspecction conditions changed (meat thickness, shape and size of the meat's particles, density, etc).

Tests carried out in the laboratory show results that reinforce these concepts and show how the signal gets worse to noise relationship when passing from UAlx or U_3Si_2 to UMo, that in this case is the worst condition (UMo used in laboratory tests is made in Korea and it is known by its spherical particles).



a)

b)

c)

Fig. 3 - Bottom echo in meat zone with a) UAlx, b) U_3Si_2 y c) UMo

The transducer that presented better behavior against the different materials was the 5MHz immersion one, with puntual focus, a crystal diameter of about 6mm and high damping.

Regarding the C-Scans it could be appreciated with enough resolution the reference reflectors, which makes this technique available to be implemented to satisfy the specification requirements [1] for the inspection of plate type fuel elements of UMo. This procedure does not assure the detection in transition zones between the meat and the cladding (fig.4) because of its ultrasonic behavior.

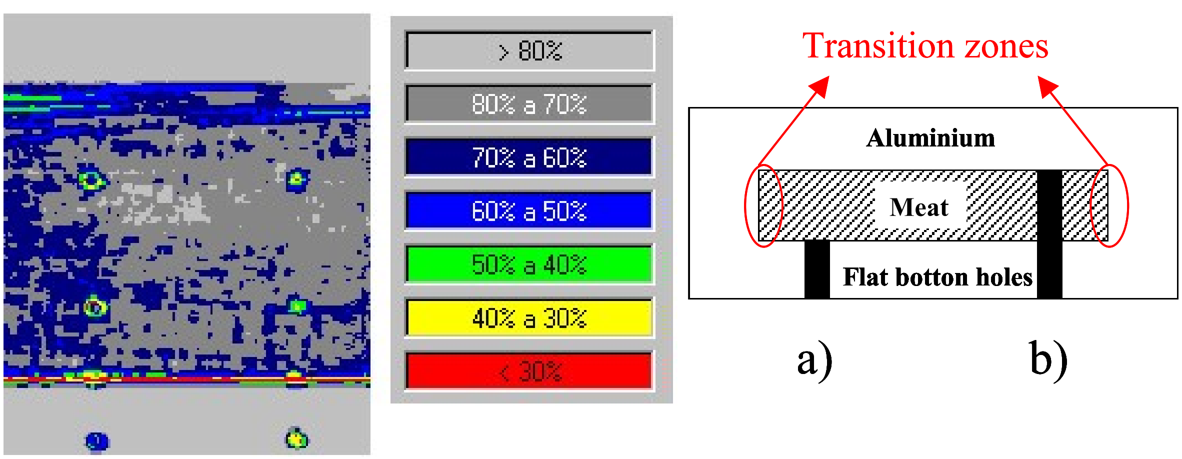


Fig. 4 - C-Scan of an UMo plate where reference reflectors of Ø 2,5mm are shown .a) 0,5mm depth, b) 1mm depth.

In case of real delaminations as that showed in fig.5, it can be seen that the system shows similar information as if it were a flat bottom hole reinforcing the concept of an ultrasonic similar behavior. In fig.5 C-Scan and metalographic examination of the unbonding zone is shown the system sensitivity against a real defect.

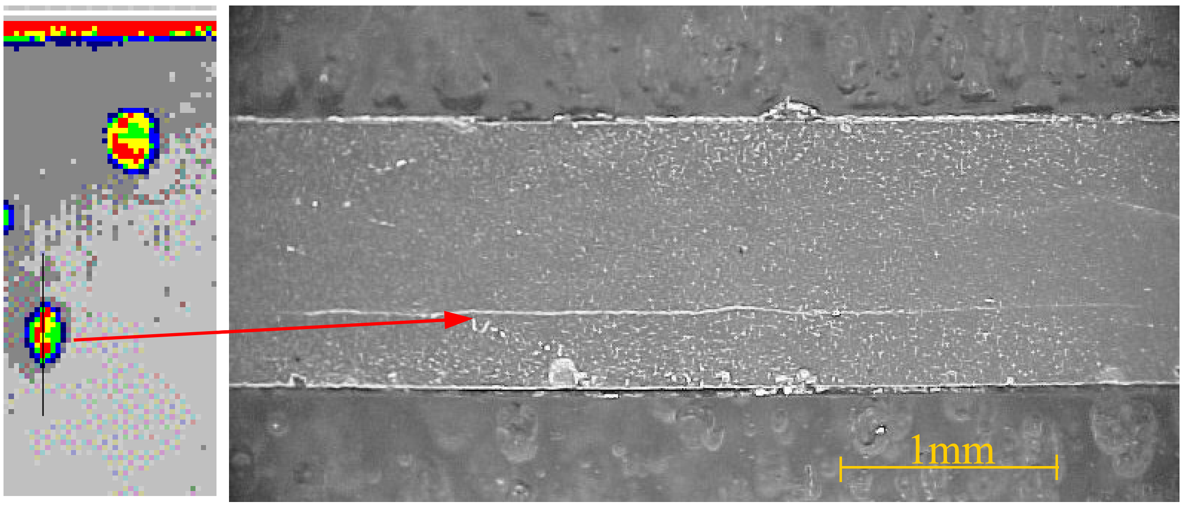


Fig. 5 - C-Scan and metalographic image of an Al plate with delamination.

Conclusions

The 5MHz transducer is the one that gathers the best characteristics to fulfill the scan; this is because of its good axial resolution and the relation between the wave length and the particles size, in opposition to the transducers with higher frequency or less axial resolution.

In the C-Scans it could be appreciated with enough resolution the reference reflectors, which makes this technique available to be implemented to satisfy the specification requirements [1] for the inspection of plate type fuel elements of UMo.

The work on inspection technique adjustment should be continued because the meat thickness, the shape and size of the particles and the density of the different compounds affect considerably the system response.

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